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Arc Welding Wire Of High Feeding Performance And Wire Drawing Method

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a wire for arc welding, and in particular, to a wire for arc welding, which has enhanced feedability by uniformly distributing residual stress of the final wire product.

Wire is added as a filler metal for the mechanism of arc welding. To be specific, wire is wound around a spool or a pail pack for welding, and passes through a feeding roller and a welding torch cable. The wire is then melted by an electric arc heating so as to be welded with a base metal. Therefore, it is critical to secure a high feedability for stable welding. Further, in the light of the recent welding work seeking automation and high efficiency, it is mandatory to provide a stable feeding of wire in a rapid feeding velocity. Thus, the demand for enhancing feedability of wire is increasing.

2. Description of the Related Art

In a variety of wires including the one for arc welding, an initial rod passes through dies of diverse sizes, and is drawn to be a final wire product after undergoing steps of reducing diameter thereof to be thinner.

In the wire drawing process, the factors related to wire feedability may be a wire drawing schedule in accordance with the reducing ratio for drawing the wire to have a desired diameter, distribution of internal stress through adjustment of deviation of a tensile strength or an drawing ratio of wire, straightness of wire, etc. Of those, an uniform

distribution of internal stress of the wire is a critical factor to be considered in enhancing the wire feedability.

The conventional method of controlling a wire drawing process to enhance feedability of the wire was limited to considering a reduction ratio only to reduce the thick diameter of the wire to be thinner or an uniform distribution of the internal stress through adjustment of deviation of a tensile strength or a drawing ratio of the wire.

As the drawing of wire is repeated in the wire drawing process, however, the external portion of the wire, i.e., the surface of the wire, with which the dies are in contact, becomes denser than central portion of the wire and is hardened. As the surface of the wire is hardened, it is impossible to draw a wire, and the distribution of residual stress between the external portion and the central portion of the wire becomes irregular. Therefore, the conventional control focused on a mere adjustment of the wire drawing schedule in accordance with the reducing ratio or an adjustment of the tensile strength has a limit in achieving a uniform distribution of residual stress between outside and inside of the final wire product.

Further, the hardness of surface of the wire resulting from the repeated drawing thereof causes an abrasion of the dies, which are in contact with the wire, and causes irregular surface and damaged surface of the drawn wire, thereby lowering the quality of a final wire product and preventing a smooth wire feeding in the course of welding.

The abrasion of dies caused by contact with wire having a hardened surface results in an irregular contact area, which is in contact with the wire, and further results in an irregular distribution of the residual stress in the longitudinal direction of the final wire product. Accordingly, when the wire passes through a feeding roller and a welding torch cable in the course of welding, the load is partially concentrated, thereby causing failure of wire feeding because of entanglement and twist of the wire.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to enhance a feedability of a wire for arc welding by uniformly distributing an internal stress of the wire through adjustment of the hardness deviation of a cross section and in a longitudinal direction of the wire in the wire drawing process.

Another object of the present invention is to provide a wire for arc welding having a uniform distribution of residual stress of the wire by controlling an area, in which the wire is in contact with dies, and by reducing hardness deviation of the wire.

Still another object of the invention is to provide a method of drawing a wire for arc welding that divides the final wire drawing step in an ordinary wire drawing process into two steps, whereby a hardness deviation between a central portion of the cross section and a surface of the wire is reduced through adjustment of the contact angle between the wire and the dies in the first step, and the hardness deviation in the longitudinal direction of the wire is reduced through adjustment of the length of a bearing part in which the wire is corrected.

To achieve the above objects, there is provided a wire for arc welding having a hardness deviation of less than 18 between a central portion and a surface of a cross section of the wire, and a hardness deviation of less than 15 between each interval of 200mm in a longitudinal direction when measured by an Hv1 hardness tester.

The hardness deviation of the wire is adjustable through control of the area, in which the wire is in contact with dies. The present invention is characterized by adjusting the hardness deviation of the wire by adjusting the contact area ratio defined by the following formula.

Contact area ratio = Reduction contact ratio (Reduction contact area/Cross section area of an incoming wire) + Correction contact ratio (Correction contact area/Cross section area

of an outgoing wire)

As a technical concept to achieve the above objects, there is also provided a method of drawing a wire for arc welding to have a desired diameter, the method of finally drawing a wire comprising the steps of: reducing a hardness deviation between a central portion and a surface of a cross section of the wire through adjustment of a contact angle between the wire and dies; and reducing a hardness deviation in the longitudinal direction of the wire through adjustment of the length of a bearing part in which the wire is corrected.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1A is a transversal section view of a wire passing through a feeding roller;

Fig. 1B is a longitudinal section view of a wire passing through a feeding roller;

Fig. 2 is a diagram illustrating a reduction contact area and a correction contact area when a wire passes through dies;

Fig. 3 is a diagram illustrating two divided steps of a final wire drawing process according to the present invention; and

Fig. 4 is a diagram illustrating a method of testing a feedability of a wire (2-turn feedability test) according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail since they would obscure the

invention in unnecessary detail.

Fig. 2 is a diagram illustrating a reduction contact area 20 and a correction contact area 200 when a wire W passes through dies D.

The contact area between the wire W and the dies D is mainly determined by the following factors: i) a contact area of the dies D with the wire W in which actual reduction of the wire W is performed; and ii) straightness of the wire and a contact area of the wire W with a bearing part 200 in accordance with the straightness. The diameter of the wire is corrected by a bearing part 200 so as to have an enhanced straightness.

In case of the factor i), when the contact area of the portion where the wire W is actually reduced (i.e., the reduction contact portion) is excessively small, the difference of residual stress between inside of the (circular) section (i.e., central portion) and outside (surface) of the wire W becomes greater. This results in a greater difference of hardness between one outside and the other outside of the wire W. As a consequence, the wire W is twisted if it fails to resist continuous partial load (refer to Figs. 1A and 1B) laid thereon when the wire W passes through a feeding roller in the course of welding, thereby resulting in vibration of the tip of the wire W that might cause an arc instability. Further, when the contact area of the portion where the wire W is actually reduced is excessively large, a partial work hardening occurs, thereby lowering the quality of surface of the wire W. In the worst case, the partial stress deviation between the inside (central portion) and outside of the wire W becomes greater, thereby disabling drawing of the wire W.

In case of the factor ii), when the contact area of the wire W with the bearing part 200 is excessively small, the deviation of the internal stress in the longitudinal direction of the wire W becomes greater, and the feeding of the wire W is not smoothly performed. As a consequence, the wire W fails to bear continuous partial load laid thereon when the wire W passes through a feeding roller 1, and is entangled or twisted, thereby causing a

departure of the wire W from the feeding roller 1 or a bending of the wire W. Thus, the wire W is likely to be deformed after passing through the feeding roller 1 or a cable in the welding process. The deformed wire has no straightness after passing through a contact tip, thereby causing a defect in welding (i.e., a bead meandering).

The conventional method of controlling such a deviation of internal stress employed a manner of controlling a tensile strength or a drawing ratio of a wire product by means of a stable reduction ratio. However, this manner has a limit to controlling a stress of the external surface of the wire W receiving a load in the feeding as well as of the central portion of the wire W receiving the load from the external surface.

Under these circumstances, the inventors of the present invention have discovered and conceived the fact that the internal stress of the wire can be uniformly distributed by controlling the total area. The total area can be obtained by summing a reduction contact area, which is an area of the reduction contact portion 20 that is actually reduced when the wire W passes through dies, and a correction contact area, which is a correction contact portion 200 where diameter of the wire W is corrected.

The inventors of the present invention have discovered another fact that distribution of the residual stress of such a final wire product is closely related to a hardness deviation between the central portion of a cross section and the surface of the wire as well as to a hardness deviation in the longitudinal direction of the wire. To be specific, the inventors have discovered that the physical property of the wire itself relating to enhancement of the feedability of the wire is affected by an uniform distribution of the internal stress in accordance with the reduction of the hardness deviation of the cross section of the wire and in the longitudinal direction of the wire, and that the reduction of the hardness deviation can be achieved by controlling the contact area of the wire with the dies to be within a preferable range. With respect to control of the contact area, it is important

to control the final drawing steps in the wire drawing process.

The wire drawing process is usually performed in multiple drawing steps to produce a wire having a thin diameter. However, all the internal stress residing in the wire in the multiple drawing steps is reflected in the wire immediately before taking the final drawing step. Accordingly, it is critical to control the residual internal stress of the wire in the final drawing step.

To be specific, the final drawing step is divided into two steps as shown in Fig. 3. In the first step, the contact angle of the wire W with the dies D is lessened to reduce the hardness deviation of a cross section of the wire W and subsequently to prevent vibration of the tip of the wire W caused by distortion of the wire. In the second step, the length of the bearing part of the dies, i.e., the length of the bearing part 200, in which the wire is corrected, is elongated to reduce the hardness deviation in the longitudinal direction of the wire W and subsequently to prevent defect of welding (bead meandering) caused by bending or twisting of the wire when passing through a cable.

The present invention is characterized in that the residual stress of the wire is drastically decreased by controlling the contact area ratio to be within the range of 3-3.5, whereby the hardness deviation between the central portion of the cross section and the surface of the wire and the hardness deviation in the longitudinal direction of the wire are reduced. A contact area ratio is defined by summing a value of a reduction contact area ratio and a value of a correction contact ratio with respect to two dies.

The following is a detailed description of a preferred embodiment of the present invention.

Embodiment

To study a relation between the hardness deviation between the central portion of the cross section and the surface of the wire and the hardness deviation in the longitudinal

direction of the wire and a weldability, weldability was evaluated based on a wire for stainless, which is relatively more stressful to work hardening in the drawing process.

Table 1

Classification		Contact Area Ratio	Hardness deviation (Hv1)		Feeding Load (A)	Remarks
			Cross Section of the Wire	Longitudinal Direction		
Present Invention	1	3.4	10.5	10.4	1.8	
	2	3.3	11.0	5.0	1.5	
	3	3.1	9.5	16.1	2.2	
	4	3.5	12.8	7.3	1.7	
	5	3.0	18.5	10.5	2.1	
Comparative Example	6	2.1	20.0	16.4	2.6	
	7	2.5	18.5	15.5	2.4	
	8	2.3	19.5	16.0	2.5	
	9	2.4	18.4	15.8	2.5	
	10		14.1	3.6		Heat Treated Wire

Reduction of the wire is performed to be 5.5mm → 1.2mm, and a kind of the applicable steel is AWS ER309, JIS Y309. The feedability was tested in 2-turn form as shown in Fig. 4, and the welding condition was 190A-220V. The wire drawing process was performed in the order of: 1st drawing → heat treatment → 2nd drawing → 3rd drawing (final drawing). The final step of wire drawing step was divided into two steps, and the hardness was measured by means of a Vickers hardness tester (hereinafter, referred to as an

"Hv1") with respect to each wire after changing the contact area ratio in each of the wire drawing steps (of the final wire drawing process).

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The heat treatment is performed after the first drawing and before the final drawing. The heat treatment performed after the first drawing is the one to release the work hardening of the drawn wire for the next drawing because stainless steel is stressful to work hardening. The heat treatment performed before the final drawing is to minimize and uniformly distribute the internal residual stress of the final wire product because a distribution of the residual stress of the incoming wire is as much significant as releasing the stress of the wire when passing through dies. The heat treatment performed before the final wire drawing is also important because even if the stress is released more or less after the 1st drawing, the residual stress distribution can scarcely be achieved to a desirable extent due to the continued 2nd drawing that causes irregular distribution of the internal residual stress.

The hardness deviation of a cross section of the wire was obtained by measuring the hardness of the central portion of the section and the surface of the wire, while the hardness deviation in the longitudinal direction of the wire was obtained by consecutively measuring the hardness five times at intervals of 200mm and by arithmetically averaging the measured values (arithmetical average value of three test samples).

As described above, the final drawing (i.e., the 3rd drawing) step was divided into two steps. In the first step, the reduction contact area was controlled through adjustment of the contact angle of the wire with the dies. In the second step, the correction contact ratio, i.e., the correction contact area in the step of correcting the diameter of the drawn wire, is controlled, and the hardness deviation between the central portion of the cross section and the surface of the wire and the hardness deviation in the longitudinal direction of the wire are reduced to uniformly distribute the residual stress of the wire. In other

words, the hardness deviation of the cross section of the wire is reduced by lessening the contact angle of the wire with the dies to prevent vibration of the tip of the wire caused by twisting of the wire in the first step of the welding process. In the second step, the hardness deviation is reduced in the longitudinal direction of the wire by elongating the length of the bearing part, in which the wire is corrected, to prevent defect of welding (bead meandering) caused by bending or twisting of the wire when passing through a cable. The degree of contact angle of the wire with the dies in the first drawing step and the degree of contribution of the bearing part to the contact area ratio in the second drawing step are preferably 1/3 (1 - 1.17) - 1/2 (1.5 - 1.75), approximately, provided that the contact area ratio is 3 - 3.5.

As shown in the Table 1 above, the feeding load is most stable when the hardness deviation between the central portion and the surface of the wire, i.e., the hardness deviation of the cross section of the wire is less than 18, and the hardness deviation in the longitudinal direction is less than 15. In case of the Examples 1, 2 and 4 showing the hardness deviation between the central portion of the cross section and the surface of the wire and the hardness deviation in the longitudinal direction of the wire to be within the preferable range, the feedability becomes higher and the arc becomes stable as the feeding load becomes lower. In case of the Examples 3 and 5, however, any one of the hardness deviation values of the cross section or the longitudinal direction is out of the preferable range, and the feeding load tends to be higher. This phenomenon is because the contact area ratio is composed of summation of the reduction contact ratio and the correction contact ratio. The phenomenon also signifies that a stable feedability can be secured not only when the total of the contact area ratio is controlled within a preferable range but also when the reduction contact ratio and the correction contact ratio as well are controlled within a preferable range.

In a 2-turn welding test of a wire, arc becomes unstable when the feeding load is about 2.1. When the feeding load is higher than 2.1, however, welding can be performed but welding cannot be consecutively performed due to instability of arc.

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As described above, the feedability can be enhanced by controlling the hardness deviation between the central portion and the surface of the wire to be less than 18 and the hardness deviation at intervals of 200mm in the longitudinal direction of the wire to be less than 15, when measured by an Hv1 hardness tester so as to uniformly distribute the residual stress of the wire.

The present invention provides a wire for arc welding with uniform distribution of residual stress of the wire by controlling the contact area of the wire with dies to be within a preferable range so as to reduce hardness deviation of the wire. As a specific method, the present invention provides a wire drawing method by dividing the final drawing step into two steps.

While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.